Linking Short and Long Term Sediment Delivery to Morphology and Acoustic Properties of Continental Margins

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LONG-TERM GOAL

Develop numerical models useful for the simulation of sediment delivery and accumulation on continental margins over time scales of tens to thousands of years. Model predictions will help us understand the evolution of the sediment characterisitcs on continental margins through sea level fluctuations, climate change, and other relevant environmental factors. ONR interests include the development of a numerical predictor of the acoustic signature of remote margins based on a region's geological history.

OBJECTIVES

1) Is the rate and direction of sealevel change coupled with hinterland climate? Does the evolving landscape control the dynamics of river plumes, and thus the physical properties of depositing sedimentary units within the slope environment?
2) Is their a separation of sand from mud during a river flood, with the mud fraction deposited on the outer shelf and upper continental slope?
3) Do closely-spaced river mouths contribute to plume intermingling such that a line source is created, particularly during low sea level stands?
4) Could a short lived hyperpycnal current develop during the flooding of the Eel River and might this explain the missing sediment mass observed in the STRATAFORM project.

APPROACH

• Task B3) Develop a model of how sediment is delivered to, and accumulates on, a continental slope. Predict delivery to the shelf-slope break from fluvial point and line sources. Compare open-slope sediment delivery (distributed) with canyon-fed delivery (localized).
• Task B8) Model major influences (climate, sea-level, tectonics) on processes that control slope morphology, stratigraphy, and acoustic realizations. Model(s) to include the effects of: a) external forcing mechanisms; b) short-term and long-term delivery of sediment; c) 2-D simulations of individual mass movements (submarine slides, debris flows and turbidity currents); d) excess pore pressure on slope failure.

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WORK COMPLETED

- evaluated USGS hydrology data of the Eel River (dynamics and trends),
- developed and verified a method to predict the rating coefficients of river loads from first principle,
- developed a world river data base of drainage basin and climate characteristics, hydrological parameters, long term sediment loads and yields,
- developed a method for predicting loads and yields in ungauged river basins,
- developed a 3-D model architecture (3D SEDFLUX) able to simulate multiple river sources from the coastline,
- developed transport models of both hyperpycnal (turbidity current) (INFLO) and hypopycnal (surface) (PLUME) events,
- developed a predictive understanding of the frequency of hyperpycnal flows generated during flood events of rivers and through sea level cycles,
- included the effects of coastal currents on plume dynamics on model simulations.
- completed the construction (DURIP funds) of a state-of-the-art Floc Camera Assembly (with 250 engineered components).
- developed a psuedo-2D Eulerian model (INFLO) able to simulate an individual hyperpycnal event flowing across a continental margin at the dynamic level (1s time step) including erosion and deposition of a multigrain size load. The model was verified against observations on Saguenay Fjord and Var River events.
- developed an advanced psuedo-2D turbidity current model that has 'failed' sediment move from a debris flow to a dense turbidity current and eventually develop into to a turbidity current plume, Model was verified against Var data.
- developed a 2D multiprocess SEDFLUX model that combines the dynamics of ten individual processes that act in concert to shape continental margin. The model includes new dynamics for debris flow and turbidity currents, and storm-influenced diffusion.
- applied the 2D SEDFLUX model to the Eel River margin with runs of 2500 years assuming starting conditions of present bathymetry, modern Eel River discharge, and sea level fluctuations using observations from historical tide gauges.
- calibrated the synthetic seismic model (ECHO) with data on cores obtained from Emerald Basin, N.S.
- compiled a data base of acoustic parameters that extends modeling to a wider range of margin lithologies,
- applied seismic model (ECHO) to transport model predictions based on the dynamics of the Eel River discharge and compared results with existing seismic data sets.

RESULTS

We now have models for simulating the discharge and the sediment load of ungauged rivers flowing into the ocean. Rating coefficients relate to the annual mean discharge, long term sediment yield and latitude (a parameter that captures the both fozen soil conditions, and snow cover duration). HYDROTREND results compare favorably with USGS observations on the Eel River, including our ability to predict the 400 yr return interval (e.g. 1964) flood of the river. With such a robust model we are able to simulate past or future climate effects on the production and delivery of sediment to the ocean. We have concluded from numerical experiments that fjord basins are able to capture, in terms of textural proxies, both the natural variability associated with precipitation and temperature as well as realistic scenarios of

abrupt climate change. Open ocean basins, like the Eel River, are less likely to record the proxy record of ambient climate variability, largely since the natural climate variability is strongly dominated by infrequent and large events that do not track climate events. PLUME can now be coupled with offshore buoy data (wind and currents), to simulate the basic features of coastal plumes under flood conditions. We predict that hyperpycnal flows will occur every 10 or so years off the Eel River, lasting for a few hours to a day. Longer return-interval floods will deliver hyperpycnal flows that could last 2 to 3 days. These events will deliver much sediment directly to the continental slope and could account for the missing sediment from surface plumes.

IMPACT/APPLICATION

We are on the path to predict acoustic properties of the seafloor of continental margins, based on process based modeling and remote data input (i.e. satellites). Realistic numerical models offer the possibility of making predictions where field data is limited. The impact of floods and or storms on the acoustic character and features of continental margins can then be examined at will. SEDFLUX model is becoming an integral part of the reservoir characterization effort of MOBIL Technology Corporation. HYDROTREND and PLUME are models being considered by Raytheon-Hughes Corporation to fuse environmental data records (infrared and visible wavelengths) downloaded from satellites for the purpose of natural disaster mitigation efforts. A white paper is in place that would allow INSTAAR numerical models, such as HYDROTREND and PLUME to link with a variety of DSMP satellite data with other NOAA-generated microwave-meteorological models to provide environmental predictions in aid of the health of our coastal zone.

TRANSITIONS

Our models have been shared with Old Dominion Observatory (Swift et al.) who have incorporated them into their own modeling efforts. Model runs of the Eel River Margin have been made available to USGS participants (Field, Lee). Mike Stekler (LDEO) helped us develop a predictive subsidence subroutine. INSTAAR models have been transferred to MOBIL Technology Center. We have helped Lincoln Pratson develop a 1-D Langrangian turbidity current model (BANG). Our seismic simulator (ECHO) has been used in cooperative work with St. Anthony Falls Hydraulic Lab's flume efforts. Through our efforts, STRATAFORM has been accepted as a core project of the world IGBP-LOICZ (Land-Ocean Interaction Coastal Zone) program that includes participants from 80 countries. We have implemented Gary Parker's 1-D Lagrangian debris flow model (BING) into our 2D SEDFLUX seascape-evolution model. Provided Craig Fulthorpe (U Texas) and Greg Mountain (LDEO) an opportunity to have STRATAFORM multi-channel seismic data cleaned up by advanced industry algorithms (MOBIL Technology). Worked with Paul Hill (Dalhousie U.) to develop an advanced floc formation model using data obtained from Yukatat Bay Alaska.

RELATED PROJECTS

• MOBIL Technology Center (Cullick, Sarg, Gouveis, Levin) supported INSTAAR efforts (Bahr, Pratson, Hutton, O'Grady) to develop a data base on continental margin morphology, sedimentology, oceanography and tectonics. Parameters are being linked into super-variables to determine the effective influence of past history, ocean energy, seismic energy and sediment delivery on continental margin morphology and deposit architecture. The two STRATAFORM margins are included in the data base.

• Work with G. Parker, C. Paola (U.Minneapolis), P. Heller (U. Wyoming), L. Pratson (Duke U.) in developing a continental margin experimental tank, through the support of a NSF grant and consortium support of oil companies (MOBIL, EXXON, TEXACO, CONOCO, JAL). It is anticipated that one of the experimental runs would be on a STRATAFORM margin.
• Raytheon-Hughes has linked with the INSTAAR modeling efforts to use STRATAFORM and or other models for the development an algorithm related to fuse satellite data (infrared and visible wavelengths) and provide information on littoral sediment transport.

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